



**LMR PROGRAM** Launches Efforts  
to Improve Marine Species Monitoring

**techniques,  
equipment  
& analyses**





## New Projects Range from Hardware Upgrades to Improved Data Collection & Analysis Methods

**t**he Living Marine Resources (LMR) program recently launched several new projects to increase the capability of U.S. Navy marine species monitoring programs—programs critical to the ongoing operation of the Navy's testing and training ranges.

In order to comply with a host of federal regulations, including the Endangered Species Act and the Marine Mammal Protection Act, federal agencies must conduct environmental reviews to consider the potential impacts on the environment by their proposed actions. The Navy is responsible for meeting specific requirements for monitoring and reporting on military readiness activities involving active sonar and underwater detonations from explosives and explosive munitions. These military readiness activities include Fleet training events and Navy-funded research, development, test and evaluation activities.



To address these requirements, a set of individual range complex monitoring plans were initially developed across the various geographic regions where the Navy trains. These plans were designed as a collection of broad “studies” intended to address questions such as whether or not marine mammals and sea turtles are exposed to mid-frequency sonar at levels that result in adverse effects, and what are the behavioral responses, if any, of that exposure.

Monitoring methods used across the range complexes include field techniques such as visual surveys from vessels or airplanes, marine mammal observers aboard U.S. Navy vessels during training exercises, and passive acoustic monitoring (PAM).

PAM is a proven means of detecting and classifying vocally active marine mammals, as well as a number of fish species, through underwater microphones known as hydrophone sensors. Sensors can be moored, drifting, vessel-towed or mounted on unmanned mobile platforms.

These monitoring systems, while functional, are lacking in several areas. First, there is no single recording system standard across all Navy facilities. In addition, a unified signal processing system has yet to be identified that can efficiently sort through the massive quantity of sound files generated by these systems.

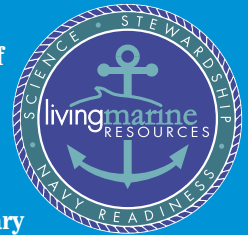
The latest projects funded by the LMR program are seeking answers to some of these questions.

## The Basics About the LMR Program

The LMR program seeks to develop, demonstrate, and assess data and technology solutions to protect living marine resources by minimizing the environmental risks of Navy at-sea training and testing activities while preserving core Navy readiness capabilities. This mission is accomplished through the following five primary focus areas:

- 1** Providing science-based information to support Navy environmental effects assessments for at-sea training and testing.
- 2** Improving knowledge of the ecology and population dynamics of marine species of concern.
- 3** Developing the scientific basis for the criteria and thresholds to measure the biological effects of Navy-generated sound.
- 4** Improving understanding of underwater sound and sound field characterization unique to assessing the biological consequences of underwater sound (as opposed to tactical applications of underwater sound or propagation loss modeling for military communications or tactical applications).
- 5** Developing technologies and methods to mitigate and monitor environmental consequences to living marine resources resulting from naval activities on at-sea training and testing ranges.

The program is sponsored by the Chief of Naval Operations Energy and Environmental Readiness Division and managed by the Naval Facilities Engineering Command out of the Naval Facilities Engineering and Expeditionary Warfare Center in Port Hueneme, California.



For more information, visit the LMR program web site at [www.lmr.navy.mil](http://www.lmr.navy.mil) or contact Anu Kumar, the LMR Program Manager at 805-982-4853, DSN: 551-4853 or [anu.kumar@navy.mil](mailto:anu.kumar@navy.mil).

# Determining the effect of sonar and other **underwater** sounds on marine mammals is difficult without a thorough understanding of how marine mammals hear.

## Getting Down to Basics

All forms of marine mammal passive acoustic monitoring can document an animal's vocal activity level before, during and after a sound event. However, determining exactly what that animal is hearing is a different story. A project team (LMR project no. 9) headed by James Finneran of the Space and Naval Warfare Systems Command (SPAWAR), Systems Center Pacific (SSC Pacific) is improving methods for determining how these animals actually hear.

In humans, noise exposure is quantified by “weighting” sound exposures to emphasize frequencies where auditory sensitivity is high. The weighting functions are obtained by asking human listeners to compare the perceived loudness of one sound to another sound at a different frequency.

A similar experiment was previously conducted at SPAWAR to measure subjective loudness levels in a bottlenose dolphin—the only time such a measurement has been done in a non-human animal (Finneran and Schlundt, 2011). This experiment, sponsored by the Office of Naval Research (ONR), consisted of a loudness comparison task, where a dolphin was trained to report which of two sequential tones was louder. While successful, the time required to train the subject and collect the data make future direct measurement of subjective loudness impractical for large numbers of individuals or more exotic species. For these reasons, follow-on studies at SPAWAR have

utilized measurements of auditory reaction time as a proxy for loudness.

Reaction time measurements only require subjects to be trained for a simple tonal detection task; however, these measurements still require access to trained animals for many weeks to collect the necessary data. This limits the number of individuals and species for whom data can be obtained, forcing extrapolations to estimate weighting functions for untested species.

The project team is exploring the use of electrophysiological measurements in obtaining hearing data for the design of marine mammal weighting functions. Electrophysiological measurements use non-invasive surface electrodes placed on subjects' heads to measure small voltages (called auditory evoked potentials (AEP)) generated by the brain and auditory nervous system in response to sound.

Previous studies have examined the feasibility of utilizing AEPs to predict perceived loudness in humans. In order to determine whether similar techniques can be used in dolphins and sea lions, a feasibility study was conducted where sounds were delivered to dolphins and sea lions while brain activity was simultaneously

monitored via surface electrodes. AEPs were measured at a variety of sound frequencies and levels. Analyses of the data demonstrated that the AEP methods did not provide a reliable prediction of subjective loudness, especially at low frequencies where data are critical for the design of Navy weighting functions.



A bottlenose dolphin during AEP measurements conducted in San Diego Bay. The AEPs are measured using surface electrodes embedded in soft suction cups placed on the dolphin's head and dorsal surface.

Simply stated, loudness is a psychological phenomenon, and this study only measured voltages generated by the brain in response to simple stimuli. While those voltages are clearly related to how the brain later interprets the loudness of a sound, they are only part of the entire story, and simply measuring them with electrodes doesn't appear to provide the complete picture of how they are processed by the brain into the psychological phenomenon of loudness.



Current research by the team is therefore focusing on identifying modifications of stimulus and recording parameters that will allow for estimation of low-frequency hearing thresholds in marine mammals, which is a type of data critical to Navy compliance documents. Protocols will also be developed for opportunistic access to novel species including stranding situations.

Determining the effect of sonar and other underwater sounds on marine mammals is difficult without a thorough understanding of how marine mammals hear and the relative effects of sounds at different frequencies. The data gathered in this project will guide the derivation of auditory weighting functions in the acoustic effects analyses sections of Navy environmental documents. The data will be applicable to all Navy documents analyzing acoustic effects of tonal sounds (e.g., sonars) and will allow for more realistic

predictions of the effects of Navy sonars and explosive sources on marine mammals.

### Expanding the PAM Range

To help answer the call for improved passive acoustic sensing technology, Principal Investigators Philip Abbot and Vince Premus are leveraging the technology and hardware they developed for two ONR-related projects.

Currently, most PAM monitoring is done with single hydrophones, which limits the range of detection coverage. While other configurations have been used (including towed, platform-mounted and drifting platforms), there is a more promising option.

For the past five years, under two separate ONR projects, Abbot and Premus from Ocean Acoustical Services and Instrumentation Systems (OASIS) have developed a system for real-time acoustic moni-

toring for surveillance purposes via autonomous underwater vehicles (AUV). This technology utilizes new acoustic sensor and digital signal processing (DSP) technology developed by OASIS, as well as existing vehicle hardware developed and maintained by the Woods Hole Oceanographic Institution. The sensor and DSP technology has previously been demonstrated using Slocum 200 and G2 gliders as its AUV, and was able to provide real-time detection of humpback whales.

For this project (LMR project no. 2), the team is utilizing a self-propelled AUV known as the REMUS 600, which has previously been used for underwater mapping and mine detection. The REMUS 600 is a faster, more powerful alternative to the gliders previously used.

Since it is self-propelled, an AUV can operate in the presence of currents, following any predetermined course.

Sei whale.

Tom Kieckhefer, NMFS Permit 14451



Since it is **self-propelled**, an AUV can operate in the presence of currents, following any predetermined course.



IRAP system during a dockside dip test. The LF sensor is coiled and suspended at the vehicle mid-section. The HF sensor is visible protruding from the underside of the vehicle a couple of feet aft of the nose.



The Integrated, Real-time Autonomous PAM (IRAP) system.

This stands in contrast to the glider, whose course is often subject to the ambient current distribution and the density profile of the water column.

The Integrated, Real-time Autonomous PAM (IRAP) system will consist of a REMUS AUV, integrated with the OASIS low- to mid-frequency (LF/MF) towed sensor and an attached High Frequency (HF) sensor. Both sensors will include onboard digital signal

processors for the autonomous detection, classification, localization, and tracking (DCLT) of vocalizations from lower frequency baleen whales and higher frequency beaked whales. DCLT contact reports will be transmitted in near real-time from the vehicle payload when surfaced, to a shore-side command and control facility via satellite. Key to the system is the autonomous processing of raw

acoustic data performed by custom software hosted on an embedded, commercial-off-the-shelf computer.

The objective of this project is to integrate and demonstrate the technology over the course of three years. Currently, the focus is on the integration of the LF/MF sensor and the humpback whale classifier (one of the marine mammal-specific classifiers previously developed and demonstrated under ONR sponsorship) into the existing REMUS AUV payload. Concurrent with this, the project team will complete data analyses for the 2013 OASIS HF sensor/G2 sea trials performed at the Navy's Atlantic Undersea Test and Evaluation Center.



In the second year, the integrated LF/MF/HF system will be demonstrated during an operational test concurrent with a regularly scheduled National Oceanic and Atmospheric Administration marine mammal survey on the east coast. Also during the second year, a beaked whale classifier will be integrated into the HF signal processor.

In the third year, the beaked whale classifier and OASIS IRAP sensors will be integrated into the REMUS AUV payload and the full IRAP system will be tested in conjunction with a full-scale U.S. Navy fleet test.

Successful demonstration of autonomous DCLT for humpback and beaked whales will provide the basis for future system enhancements such as the ability to autonomously classify a wide variety of other marine mammals.

The autonomous system will have the ability to track low-frequency baleen and high-frequency beaked whales while simultaneously monitoring the

operation of mid-frequency active sonar, thereby mitigating possible harm to these animals caused by the use of active sonar during at-sea exercises. Due to its mobility and broad-band frequency, the IRAP will also improve detection coverage over a much wider area, improving the accuracy and completeness of existing animal density estimation techniques.

### Toward Autonomous Monitoring

Another project (LMR project no. 4) is seeking to enable truly autonomous PAM by testing a glider and a float platform.

Both platforms will include an acoustic system that was developed by Oregon State University (OSU) with ONR funding. The OSU PAM board is based on an advanced digital signal processor (DSP) and low-noise pre-amplifier that achieve a signal-to-noise ratio higher than 96 decibels. The electronic noise level of this system is well below the

ambient background noise of a typical calm ocean, maximizing the listening range and detection performance in a wide variety of ocean conditions. This listening capability covers the frequency range of almost all cetaceans except for porpoises.

The DSP system has already been used in previous ONR-sponsored work with the APEX float from Teledyne Webb Research. This project will compare the APEX float with the Seaglider from Kongsberg. Both platforms are buoyancy-driven, deep-



Acoustic float descending during the off-Hawaii test.  
Ben Allsup

Short-finned pilot whales.

Jessica M. Aschettino, NMFS Permit 16239



This technology will enable the Navy to monitor marine mammals **cost-effectively** in real-time.



The Kongsberg Seaglider. The hydrophone is visible on the orange antenna.



The PAM board installed in the Kongsberg Seaglider.

diving vehicles capable of descending to 1,000 meters (glider) and 1,500 meters (float). While gliders can be steered remotely, profiler floats simply drift with the ocean current. The

advantage of the float lies in its comparatively low cost, approximately 25 percent of the cost of a glider. Although the two mobile platforms are acoustically quiet, there are

differences in body shape, steering mechanism, water flow, pump and motor activities, and internal electronics noise. These differences likely impact the passive acoustic performance of the systems and need to be examined and evaluated.

The first task undertaken under this project, headed by Haru Matsumoto of OSU, was to integrate the OSU PAM board with the Seaglider. In October 2014, OSU conducted the first engineering test of the PAM-installed Seaglider off the Oregon coast. The test provided valuable data on the system which will be used to enhance its detection capability.



In the spring of 2015, a two-week test will be conducted to compare the Seaglider's capabilities to those of a bottom-moored High-frequency Acoustic Recording Package (HARP) at the Quinault Training Range in Washington State. Subsequently, both platforms will be demonstrated with the Marine Mammal Monitoring on Navy Ranges (M3R) system at the Southern California Offshore Range (SCORE).

An additional goal of this project is to provide a more robust acoustic data set for the presence, distribution and density estimation of beaked whales.

At the end of this project, a detailed report will be issued comparing the performance of each system with the HARP and M3R systems. A detailed installation and user's guide will also be developed.

This technology will enable the Navy to monitor marine mammals cost-effectively in real-time, in areas of interest where cabled hydrophone arrays are not available or poor weather conditions prohibit ship-based visual observation.

## Leveraging Existing Algorithms to Improve Digital Signal Processing

Another LMR project (no. 8) is applying some of the analytical methods that have been developed for active and passive sonar to improve the Navy's PAM systems.

As part of his Ph.D. thesis, Principal Investigator Tyler Helble (along with his advisor, Gerald D'Spain) developed a detection algorithm known as a Generalized Power Law (GPL) processor. Power law processors are the optimal detectors for transient signals, in the situation where the signal has an unknown frequency content, location, duration, and strength. Conventional detection of humpback vocalizations is often based on the assumption that energy (square of the Fourier amplitude) is the appropriate metric. Power law processors allow for a higher power of the Fourier amplitude, appropriate when the signal occupies a limited but unknown subset of these frequencies. Simply stated, sound in the ocean is rarely

stationary, and a power law metric is a more accurate way of isolating and identifying specific sounds.

Raw counts of marine mammal call detections by themselves can be very misleading. They should be corrected for variability in environmental properties before any interpretations can be made. For instance, when ocean noise levels are very low, more humpback whales are detected. However, while the probability of detection rises during these time frames, the animals may very well have been present all along.

The GPL processor is able to detect weak transient whale vocalizations in the presence of considerable anthropogenic and biological noise. This has proven to hold true even during periods of mid-frequency active sonar transmissions typical in U.S. Navy training events. The processor has been used with great success in the collection of humpback whale data by the autonomous HARP devices that are currently being used for PAM at several Navy testing and training ranges.

When ocean noise levels are very low, more humpback whales are detected.





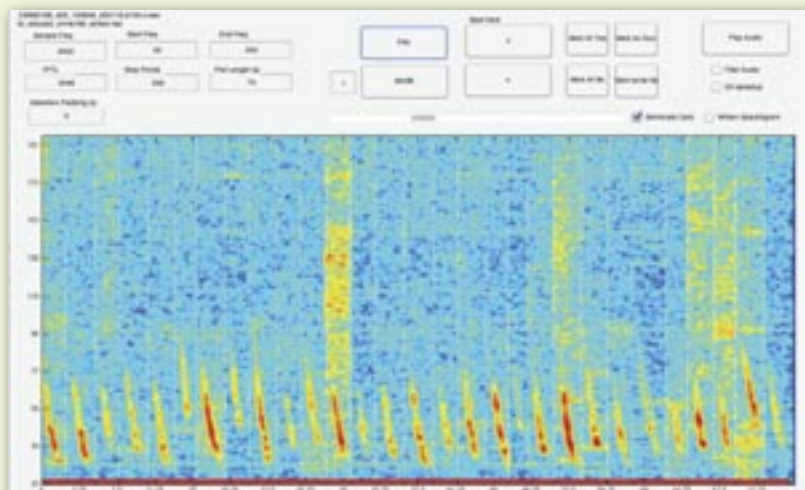
## The GPL processor is able to detect weak transient whale vocalizations in the presence of considerable anthropogenic and biological noise.

Any algorithms developed for GPL processing are constrained by the need for pre-processing adaptation to accommodate the ambient noise at each location, as well as the noise created by the platform itself. In addition, ocean bathymetry greatly influences PAM readings. For these reasons, the creation of a fully automated system is not feasible. This project will design a system that “calls out” potential signals of interest for examination by a human operator.

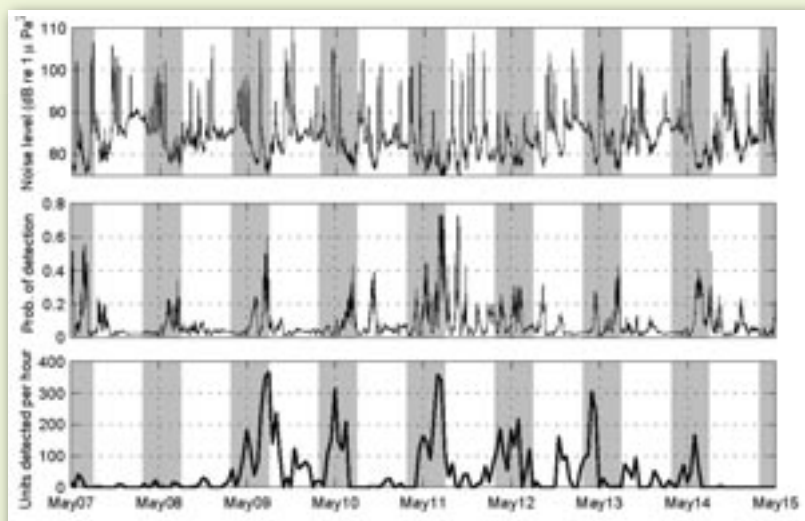
Working closely with other LMR-sponsored project teams, the team will first adjust GPL algorithms for use with specific marine mammals and then test and implement these algorithms using data from existing Naval Facilities Engineering Command PAM systems, including SCORE and the Pacific Missile Range Facility (PMRF) in Kauai Hawaii.

To date, the project team has tuned and calibrated the GPL detectors for three species (humpbacks, minke and blue whales) from HARP recordings deployed throughout southern California. An auto-tuning algorithm for baleen whales has also been created using the PMRF data.

This project will improve the Navy’s PAM capabilities in two critical areas. First, it will implement automated detectors optimized for specific marine mammal species that will filter down the massive amount of recorded data, vastly reducing the time and cost for human operators to manually examine a data set. This effort will also provide the methods for calibrating the detector output call counts for spatially and temporally varying ocean environmental conditions.



Spectrograms of GPL detections shown in the GUI for blue whale D calls. The GUI allows the operator to quickly accept/reject detections provided by the GPL.



Comparison of raw (uncalibrated) humpback call detections with temporal changes in ocean noise levels, and the resulting changes in the probability of detection.

The end result of this project will be a software package containing all pre-processing and detection software and the graphical user interfaces (GUI). Implementation of this technology at Navy sites will increase computational costs (and may require acquisition of additional computer resources), but will vastly reduce human operator time required to examine the passive acoustic recordings. Therefore, a significant net cost (and time) savings are expected.



## New Interface Will Triple Data Storage Capability

The HARP system, currently used on several Navy ranges for marine mammal passive acoustic monitoring, is a state-of-the-art recording system that features high bandwidth (up to 160 kilohertz) and large data storage (five terabytes (TB)) combined with low power requirements. While there is no issue with HARP performance, the amount of data this system generates is overwhelming its current storage capabilities.

Current HARP data storage is based on Integrated Drive Electronics (IDE), a standard electronic interface for disk storage devices, originally developed by Western Digital and adopted by the American National Standards Institute (ANSI) in 1990. (After adoption, ANSI changed the name to

Advanced Technology Attachment (ATA).) More recently the Serial ATA (SATA) interface has become the industry standard. Serial ATA offers several advantages over the parallel ATA interface—reduced cable size and cost, and faster and more efficient data transfer. Just as important, the currently used IDE disks are no longer available, so an upgrade to SATA disks is necessary to keep the Navy's HARP systems serviceable.

The current HARP system has a maximum storage capacity of five TBs or ten TB compressed storage. Once the SATA interface is installed, HARP storage capacity will be dramatically increased to 16 TB (32 TB compressed) based on currently available hard disk drives. It is anticipated that this capacity will increase as disks with larger capacities

become available, as has been the case for this technology throughout the years.

This project (LMR project no. 7), headed by John Hildebrand of Scripps Institution of Oceanography,



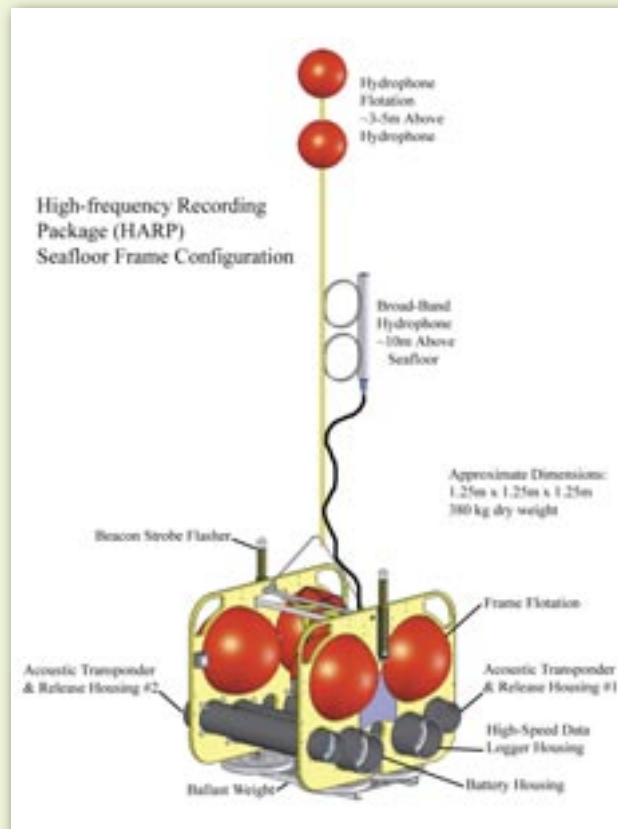
The current HARP data logger electronics attached to a pressure housing endcap with electrical feed-thru connectors. The modular data logger consists of five removable circuit boards to allow for ease in upgrading and repair, and an array of 16 IDE hard disk drives for long-term high-bandwidth data storage.



Sperm whale.  
Suzanne E. Yin, NMFS Permit 14451



The **modular** nature of the HARP electronics should allow upgrading by replacement of a select set of electronics boards, rather than the need to replace the entire system.



The HARP system was developed by Sean Wiggins, John Hildebrand and their colleagues at the Scripps Institution of Oceanography.

will first design the HARP electronic disk interface. Subsequently, it will be installed on a HARP system and tested, first at sea, and then on a Navy range. After a deployment of several months, data from the new system will be analyzed. Assuming acceptable performance, the SATA drives will be installed on all 13 existing Navy HARP systems. The modular nature of the HARP electronics should allow upgrading by replacement of a select set of electronics boards, rather than the need to replace the entire system.

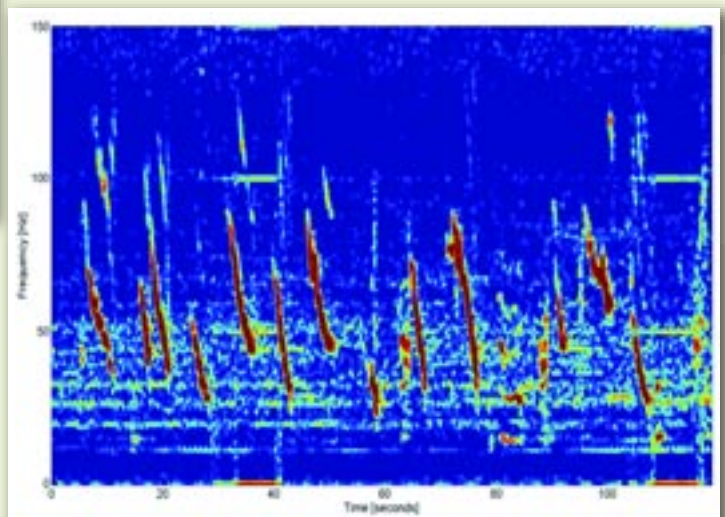
Upgrade of currently deployed HARPs for SATA disk storage capacity will yield reduced costs per deployment and potentially fewer service trips for sites that are difficult or expensive to access. The project is expected to be completed in the spring of 2016.

## Making Sense of All That Data

As mentioned above, the amount of data generated by the current HARP marine monitoring system is overwhelming its current storage capabilities. This amount of data can also be overwhelming and costly to process.

This project intends to simplify the data management process so that non-expert users can access and process the data gathered by monitoring systems.

The current state-of-the art for processing large PAM data sets in the Navy is a hybrid between manual scanning of the data and automatic call detection. This approach allows accurate analysis of large data volumes—and is the baseline against which the efficiency of automatic detection and classification algorithms must be compared.



Recorded blue whale D calls, often made during foraging activity.

This project (LMR project no. 6) will develop metrics for assessing the performance of existing and future data processing algorithms for PAM data. To do so, the team will construct marine mammal sound datasets specific to each naval training area, then compose a standardized set of metrics to assess the performance of both existing algorithms and potential new algorithms.

During the first year, the project team is compiling an extensive set of training and test data based on acoustic recordings already collected at naval training areas on the west coast. In later years, they will examine data from the east coast and central/western Pacific. This work will be undertaken by co-Principal Investigators John Hildebrand, Simone Baumann-Pickering and Ana Sirovic of Scripps Institution of Oceanography and Marie Roch of San Diego State University.

Each dataset will be focused on particular species and signal types, and will sample the range of variability of the signal, the ocean noise environment in which the signals occur, seasonal variables, and the contribution of variations in the recording system. The team is focusing on species that are found across multiple naval training sites, that are relatively ubiquitous, and whose signals are well characterized, such as blue, fin and humpback whales, a variety of beaked whales, and Risso's dolphins. A category of unidentified cetacean signals will also be labeled.

These data will be shared with the marine mammal researcher community for use in developing automatic algorithms related to call detection and classification. This protocol follows the well-developed path of the Advanced Processor Build program utilized in the Anti-Submarine Warfare community.

A parallel effort will engage the marine mammal detection and classification community to develop a standardized set of metrics for evaluating automatic detector and classification outputs. The first year will focus on metrics for baleen whale calls. Later years will consider odontocete (toothed whale) signals. These metrics will then be universally applicable to both existing and potential new automatic detection algorithms for specific baleen whale calls and odontocete signals.

New algorithms can be promulgated to all U.S. Navy-funded PAM operators once they have been demonstrated to provide the necessary recall and precision for a particular species call.

The ultimate goal is to develop a comprehensive dataset of marine

mammal calls for use in the development of robust detectors and classifiers—one that covers the full range of species of interest at every training location. Automated methods to detect and classify marine mammal sounds would simplify data analysis and reduce data processing costs.

### **The Challenges Associated with Auto Detection**

As stated above, the large and increasing volume of acoustic data collected by marine mammal passive acoustic monitoring systems is difficult to process and interpret in a timely manner. In order for this state-of-the-art technology to be efficiently utilized, software for detection and classification of sounds produced by marine mammals is needed.

The variability inherent in many sounds produced by odontocetes (toothed whales such as dolphins and beaked whales) and the overlap in time-frequency characteristics among species, makes it difficult to automatically detect and classify them. Sounds produced by odontocetes can be

The team will focus on species, such as humpback whales, that are found across multiple naval training sites and have well-characterized signals.





## An automated classifier that includes information from both whistles and clicks would advance the science of automatic classification.

grouped into one of two broad categories—whistles and pulsed sounds (clicks).

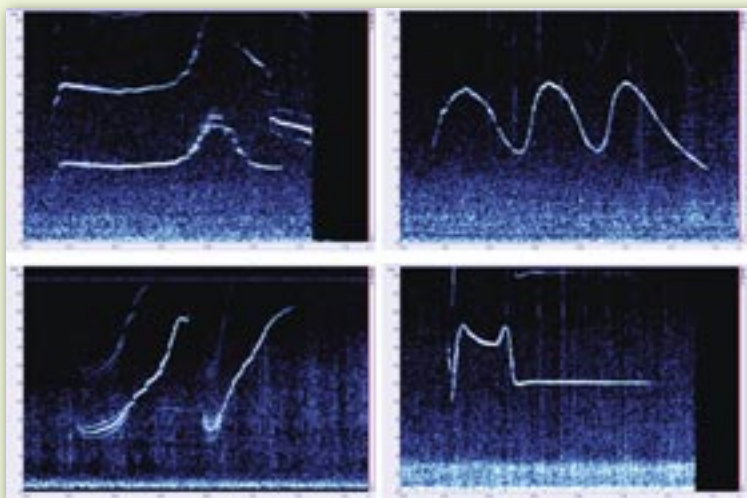
Previously, separate whistle and click classifiers have been developed for specific dolphin species. However, not all species produce whistles, or they may only produce whistles or clicks in specific behavioral contexts. Therefore, an automated classifier that includes information from both whistles and clicks would advance the science of automatic classification. In addition, including information about acoustic behavior and the specific location where a recording was made may also increase classification success. A classifier that is able to combine information from different types of sounds as well as information pertaining to behavior and location may be more successful in identifying species than one that only considers one sound-type at a time.

It is the goal of this project team to develop such classifiers. Using acoustic recordings from the Western Atlantic Ocean, Principal Investigators Julie Oswald and Tina Yack of Bio-Waves Inc., will first detect/extract whistles using three different automated tonal detectors. The output of the three automated detectors will be tested and compared for accuracy. The detector that exhibits the best performance will then be integrated with an existing whistle classifier software (the Real-time Odontocete Call Classification Algorithm (called ROCCA)). ROCCA currently is available as a module in the marine mammal passive acoustic processing program called PAMGuard.

Clicks will be detected and measured using PAMGuard's automated click detector. The click detector will send measurements to ROCCA for classification analysis. Finally, in a related ONR-funded effort, 'behavior and location' feature vectors will be created and tests will be run to determine how best to include them in the classifier. Classification models will then be developed that identify encounters to species based on all of the available feature vectors. Methods will be developed and tested during the ONR



The variability inherent in many sounds produced by odontocetes such as striped dolphins makes it difficult to automatically detect and classify them.



Whistles, clicks and pulsed calls produced by killer whales.

portion of this project using data from the northwest Atlantic and Hawaii. The classification approach developed in the ONR portion of the project will then be used to create classifiers for species in the temperate Pacific Ocean. This portion of the project will be funded by the LMR program.

At the end of the project, all new classifiers will be integrated into PAMGuard and another software platform for processing acoustic data, Ishmael. Current users of PAMGuard and Ishmael software will be able to download the updated versions as soon as they are available.

The fully automated methods developed under this project will significantly reduce the time and cost required for the processing of PAM data. In addition, adding classifiers for clicks and behavior/location data is expected to provide better classifications and therefore a more accurate representation of species distribution on and around Navy training ranges.

## Improving the Software

Another team sponsored by the LMR program is approaching the problem of marine mammal sound classification by testing the accuracy of the detectors and classifiers currently in use.

In order to detect and classify marine mammals, specific characteristics of their signals must be extracted from the audio signal received by the PAM system. A project team headed by Dave Mellinger of OSU (under LMR project no. 3) is creating a database of performance-characterized detectors/classifiers for many marine mammal species that can be integrated into the current PAM software package called Ishmael. (A detector is a file that detects a sound and a classifier categorizes the sound according to species.) The Ishmael program, originally developed by Mellinger with ONR funding, is one of the most popular bioacoustics programs used in the field today. It includes displays of sound waveforms and spectrograms, recording capability for real-time input, and several methods for acoustic localization and automatic call recognition.

The detectors/classifiers currently in the PAM system database will be characterized and evaluated by

testing them against sound files found at [www.mobysound.org](http://www.mobysound.org). This web site houses a publicly accessible archive of sound recordings of over 35 marine mammal species. MobySound recordings have been annotated to indicate where (in time and frequency) each call occurs and what its signal-to-noise ratio is—information crucial to evaluating detector/classifier performance.

To achieve this, the Ishmael software interface is being enhanced so that it can communicate seamlessly with MATLAB, a language widely used to easily implement detectors and classifiers.

An online database of detectors/classifiers will be built for beaked, sperm, and baleen whales.

*Tim Cole, Permit 775-1600-10*

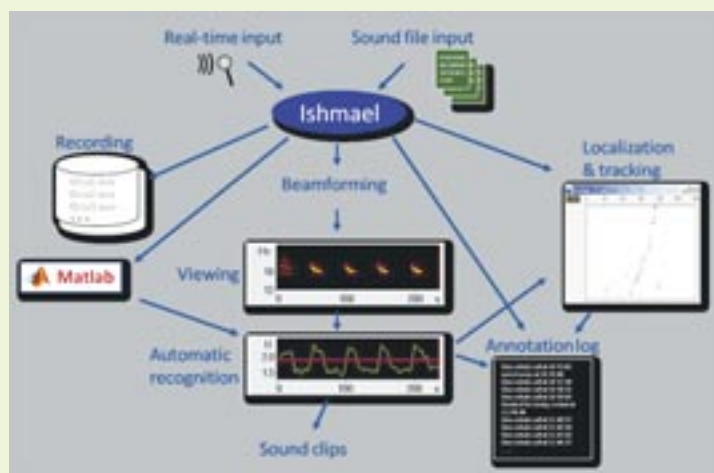


Killer whale.





A relatively naive user will be able to sit down, choose what species to monitor, and the system will provide **detections** and other performance measures for those species.



Components of Ishmael.

Then, an online database of detectors/classifiers will be built for beaked, sperm, and baleen whales as well as a number of delphinids (small to medium cetaceans, such as pilot whales and dolphins). These detectors/classifiers will then be tested against the sound files in MobySound to provide performance information for each one.

By early 2017, an Ishmael-to-database interface will be created to display detectors and performance data in Ishmael and make it simple to download and install any of the available detectors/classifiers. This will be followed by documentation and training for Navy personnel and private (contractor) marine mammal observers as well as regulators who are involved in Navy mitigation issues. Training will be provided by adding a new module to an existing Bio-Waves training course for passive acoustics technicians. Stand-alone training on the new software will also be available.

When this new software is integrated into Ishmael, a relatively naive user will be able to sit down, choose what species to monitor, and the system will provide detections and other performance measures for those species.

Having a system for marine mammal detection that is both straightforward to use and well-characterized will make adoption of acoustic monitoring faster, easier, and therefore more widespread within the Navy, enabling easier compliance with environmental law and practice.

## Expanding the Knowledge Base

Currently, the single most cited resource for information on the effects of noise on marine mammals is a book that was published in 1995 (*Marine Mammals and Noise*, Academic Press, San Diego). This book has been a valuable resource for the Navy, environmental planners, regulators and scientists. However, in the last 20 years the literature related to the issue of marine mammals and noise has expanded greatly and there is more information to consider when assessing effects of noise on marine mammals. There is a pressing need to update this book that is shared by multiple stakeholders who rely heavily this resource.

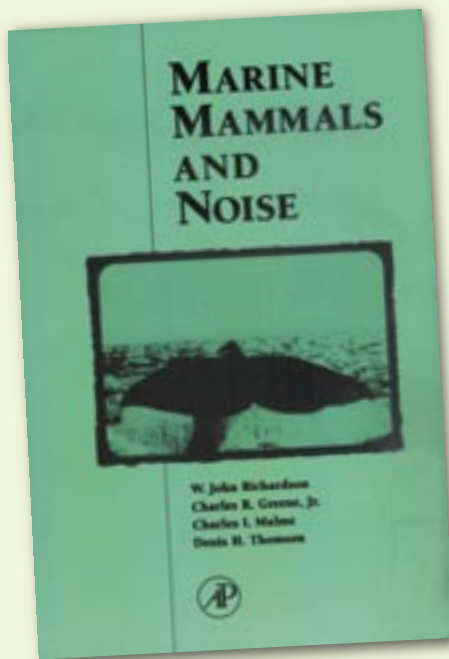
Since there are many stakeholders involved and the effort is so large, this project is leveraged with funding from ONR, the National Marine Fisheries Service, and the Joint Industry Program. The LMR component of the project is led by Christine Erbe, Director of the Center for Marine Science & Technology at Curtin University, Australia.

The tasks to be undertaken during the LMR portion of this effort include:

1. Developing a publicly accessible database of literature on marine mammal bioacoustics.
2. Reviewing the literature and publicly available data on the sounds produced by marine mammals and on marine mammal hearing.
3. Preparing a subsequent essay on how marine mammal bioacoustic data can inform both conservation efforts and the management of marine resources based on the literature review conducted.

Members of the project team have their own research database from which to gather information. The team will also actively solicit articles and reports from the scientific community, including “grey” literature (reports that were not published in scientific journals). The team members will assemble all relevant information into a publicly accessible database of literature on marine mammal bioacoustics. The information gathered in this

project will be summarized into two final reports—one on marine mammal sound generation and a second on marine mammal hearing. An essay will also be published summarizing the overall findings.



*Marine Mammals and Noise*, published in 1995, is the single most cited source for marine mammal data. This LMR project will develop an updated source for information on marine mammal bioacoustics.

Once this project is complete at the end of fiscal year 2016, the team will leverage this work and solicit sufficient additional funds to produce a book compiling the team's findings.

All stakeholders concerned about the impact of anthropogenic noise on marine mammals would benefit from the first single source in 20 years to bring together available research on marine mammal sound production and hearing. It is expected that an updated, authoritative information source would also help alleviate overly conservative values sometimes used by regulators. The project's final essay will provide Navy-specific recommendations.

### Facilitating the Permitting Process

The Navy commits significant funding and manpower to improve understanding of the occurrence, exposure, response, and consequences of marine mammals within and near Navy at-sea training and testing activities. The research and technologies supported by LMR have two over-arching goals:

1. To improve the available information regarding the potential impacts to marine mammals from Navy activities.
2. To improve the technology available to the U.S. Navy marine species monitoring program.

The information garnered from these efforts will inform the Navy's at-sea environmental compliance and permitting processes and lead to improved impact analysis, marine mammal take estimates, and mitigation measures.

Downloadable (pdf) summaries of all of these projects are available on the LMR web site at [www.lmr.navy.mil/ProjectHighlights.aspx](http://www.lmr.navy.mil/ProjectHighlights.aspx). [🔗](#)

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